

RESEARCH AND EDUCATION

OPERATIONS RESEARCH CURRICULA PRODUCE DECISION-MAKERS

Two curricula, Operations Analysis and Operational Logistics, lead to the degree Master of Science in Operations Research (OR). Taught in the Department of Operations Research at the Naval Postgraduate School, both curricula emphasize the use of mathematical modeling, simulation and analysis to help people make better decisions. Both include a six-week experience tour where students typically visit an operational command to test their skills on real problems. The experience tour is the real-world laboratory for the curricula and is usually the client for the thesis research subsequently performed by the student.

The Operations Analysis (OA) Curriculum was established by the Navy in 1951 when it recognized that the OR concepts and techniques pioneered in WWII were worth preserving. OA is the development and application of mathematical models, statistical analyses, simulations, analytical reasoning and common sense to the improvement of real-world operations. Practitioners are called upon to advise military and civilian decision-makers on the allocation of scarce resources, the selection of new equipment and processes, and the optimal deployment of given resources to achieve required missions.

Mathematics, probability, statistics, economics, human factors, and optimization supply the theoretical background for analyzing alternative choices in tactical and strategic

warfare, and in planning, budgeting and acquisition of systems and forces. The student learns computational methods and develops skills to identify relevant information, formulate decision criteria and select alternatives. The Navy sponsor for the OA curriculum is the Office of Chief of Naval Operations, Assessment Division (N81).

The Operational Logistics (OL) Curriculum was initiated in 1986 by the Deputy Chief of Naval Operations (Logistics) and supports the Operational Logistics subspecialty (xx43). There are subspecialty billets in the Joint Chiefs of Staff, OPNAV, Fleet CINCs, and afloat staffs. Students have included officers of the Navy, Marine Corps, and Army. Navy students have included all warfare specialties, fleet support, and staff corps.

The OL curriculum is strongly related to the OA curriculum and shares course work in mathematics, probability and statistics, computing and simulation, optimization, and warfare modeling and analysis. The focus on operational logistics is created through unique courses on naval and joint logistics, defense transportation systems, logistics models, and special operational logistics seminars.

The education provided in the Operations Analysis and Operational Logistics programs enhances performance in all duties throughout a military career including operational

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MILITARY OPERATIONS RESEARCH SOCIETY AWARD

LT Gregory Chapman, USN (June 2000) has just won the Stephen A. Tisdale Award of the Military Operations Research Society for best Masters thesis in Operations Research (OR) at NPS. His thesis optimizes the inventory policy for the Marine Corps Research Institutes (MCIs) course materials. The new policy promises to reduce cost, shortages and warehouse space. LT Chapman was advised by CDR Kevin Maher, SC, USN.

MCI is the distance learning center for the United States Marine Corps. MCI's mission is to develop, publish, distribute, and administer distance training and education materials to enhance, support or develop required skills and knowledge of Marines. It also satisfies other training and education requirements as identified by the Commanding General, Marine Corps Combat Development Command.

To meet this mission, MCI develops and assembles course materials ranging from simple training courses to college-level Professional Military Education (PME) programs. Each course or program consists of multiple components that must be printed, stocked, and distributed to all Marines. Currently MCI offers 151 courses comprising 305 printed components; in 1999, MCI

processed over half a million requests for course materials.

Early last year, MCI recognized the need to improve their inventory control processes and services levels by optimizing reorder points and reorder quantities for course materials. LT Chapman spent five weeks with MCI and went on to develop an inventory model — a non-linear program — to set those reorder points and quantities and thereby minimize shortages. Shortages are incurred for orders that cannot be filled immediately, and MCI had too many.

Inventory theory is an active area of study within OR, and LT Chapman's thesis is based on and extends this theory. Results from the thesis indicate that shortages can be reduced from about 10,000 per year to a few hundred, and that warehouse space can be reduced 30%-50%. The Marine Corps is implementing the model, and its advice, immediately.

LT Chapman began the Operational Logistics curriculum, in the OR Department at the Naval Postgraduate School, in June 1998. His next assignment returns him to Newport, Rhode Island, for Surface Warfare Officer School, Department Head Course, commencing July 2000.

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billets, technical management assignments, and policy-making positions. As with all NPS curricula, OR blends education and research to produce a synergy between students, faculty and sponsors. Highlighted below are a few samples of this synergy at work.

Distributing Intra-Theater Wartime POL Requirements

The Commander-in-Chief, United States Pacific Command (USCINCPAC) must ensure sufficient storage and distribution assets are available to satisfy wartime petroleum, oil, and lubrication (POL) requirements in the Pacific Theater. Prior to the thesis of **LCDR Tracy Keenan, SC, USN** (September 1999), USCINCPAC did not have a model to determine if planned re-supply and intra-theater transportation assets (pipelines, railcars, tank trucks and tankers) could satisfy wartime POL requirements. Solving USCINCPAC's worst-case scenario for U.S. forces in Japan (spanning 120 days and total POL requirements of 26 million barrels), her model shows that requirements cannot be satisfied with existing infrastructure and transportation assets. But, her analyses also show ways to eliminate these shortfalls. Operations Research Associate Professor **Robert Dell**, LCDR Keenan's thesis advisor, has continued to use her model to help USCINCPAC plan infrastructure improvements.

Earlier this year, the USCINCPAC Director for Logistics, Brigadier General Philip Mattox, USA, wrote to the NPS Superintendent saying, "My staff and I are extremely impressed with LCDR Keenan's thesis entitled 'Distributing Intra-theater Wartime POL Requirements.' LCDR Keenan's dedication in researching this issue is very much appreciated and worthy of recognition."

A Decision Support System for Sea-Based Sustainment Operations

Building a sea-based logistics decision-support system (DSS) for MEU-sized operations was the thrust of the thesis of **Capt Norman Reitter, USMC** (September 1999). The DSS was built to facilitate the collaborative mission planning and dialogue between operators and logisticians. The need for such capabilities has been noted in other studies. This issue has been of continuing interest to Distinguished Professor **David A. Schrady**, who was Capt Reitter's advisor. The principal entities modeled in the DSS are forces and transport aircraft. In the setup phase, the force required for a given mission is modeled by selecting from a menu of combat, combat support, and combat service support force components. The combat forces range from an infantry fireteam to

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UNITED STATES ARMY CHIEF OF STAFF AWARD

MAJ Wade S. Yamada, USA (June 2000) has been awarded the United States Army Chief of Staff Annual Award for Excellence in Operations Research. He won the award for his thesis research that developed manpower planning models to forecast Army officer inventory. His thesis advisor was Associate Professor **Siriphong Lawphongpanich** in the Department of Operations Research.

Within the Military Strength and Forecasting Division, Office of the Deputy Chief of Staff for Personnel (ODCSPER), United States Army, military analysts utilize various tools/decision aids to forecast Army officer inventory. Current tools/decision aids are implemented in a spreadsheet and lack a component that optimizes various management controls for shaping or regulating the officer inventory. These controls include accession, promotion, and, when necessary, separation, typically via some early retirement programs. Past attempts to develop optimization models to aid in the forecasting and management of the officer inventory were not successful. These models recommended unfamiliar management decisions and required too much time to obtain a solution. In one case, the model must be executed overnight on a mainframe

computer.

MAJ Yamada's thesis develops an optimization model that addresses the officer inventory at a more aggregate level and requires considerably less time (less than a few minutes) to solve. The main goal with the proposed model is to permit analysts the ability to perform what-if analysis quickly and to enhance its usability by allowing the model to be implemented or interfaced with a spreadsheet.

In theory, the planning horizon for most manpower planning models is infinite. However, the horizon is often truncated to a much shorter interval, e.g., between 5 and 30 years, in practice. Doing so produces errors known as end effects. The thesis uses techniques known in the literature as primal and dual equilibrium in combination with a new sampling scheme to reduce end effects as well as the size of the resulting model. Historical data are used to illustrate the models applications under scenarios suggested by ODCSPER analysts.

Upon graduation, MAJ Yamada will be assigned to the Military Strength Analysis and Forecasting Division, Office of the Deputy Chief of Staff for Personnel (ODCSPER), to serve as an officer personnel analyst.

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an infantry battalion. Combat support forces include an artillery battery, LAV detachment, AAV detachment, tank platoon, combat engineering detachment, and some combat service support units. Each force component has its associated logistics planning factors for rations, water, fuel, and ammunition. When the force is identified, its logistic support requirements are automatically aggregated. The next part of the DSS is the set of events in which the force participates over time. While rations and water are consumed daily independent of the activities or events of the force, the use of fuel and ammunition depends on events. The force events are movement to objective, assault, defense, etc. The force events are the means for reflecting the commanders concept of operations. Aircraft events include resupply, troop movement, and MEDEVAC. In recognition of the competition between operations and logistics for air assets discovered earlier, the DSS has an automated transport aircraft scheduler.

Since the number of MV-22 and CH-53E aircraft available in an amphibious readiness group is finite, Capt Reitter modeled each aircraft individually in terms of its accumulated flight hours, hours until its next maintenance action, and crew hours on a given day. His scheduler assigns available aircraft based upon lift requirements, distances, and other information. Multi-task sorties can be scheduled; i.e., transport fuel from the sea base to site A, move troops from

site A to site B, and return to the sea base with casualties from site B. Infeasibilities, for example the requirement for more sorties in a given period of time than the available aircraft can generate, can be found during planning performed within the DSS and this allows the plan to be modified accordingly.

Large Scale Network Algorithms

LT Matt Gibbons, USN (June 2000) advised by Professor Kevin Wood, is developing and implementing an algorithm for network analysis in a project sponsored by the National Security Agency (NSA). A "minimum-capacity cutset" in a network can represent the optimal set of links (or nodes) in that network to intercept (eavesdrop on) or cut (interdict) all communications traveling between, say, a central military commander and a distant field commander. Secondary criteria, e.g., safety of interceptors, collateral damage, etc., can make strictly optimal solutions undesirable, however. One approach to dealing with this problem is to enumerate a large set of "near-minimum cutsets," and filter those against the secondary criteria. This enumeration is the focus of the new algorithm.

A lot of supercomputer time has been spent, in a brute force manner, enumerating all cutsets in networks. This may be useful for some problems, but is hopeless for normal road and communications networks because the number of cutsets

increases exponentially with the size of such networks. Another approach to the problem is to enumerate all minimum (-capacity) cutsets: NSA already has efficient computer codes to solve this problem. But, the set of minimum cutsets may not be rich enough to allow for much flexibility with respect to the secondary criteria. NSA wants to look at near-minimum cutsets, efficiently.

The algorithm being developed is based on a tree-enumeration that includes and excludes certain arcs from the next potential near-minimum cutset. Special backtracking rules limit the amount of enumeration needed: Some rules are simple, e.g., backtrack if the total included capacity exceeds the total allowed, and some are more complicated, e.g., backtrack if the implied values of dual variables (from linear-programming duality theory) are contradictory. The algorithm is coded in Java and is already

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INFORMS AWARD FOR THE TEACHING OF OPERATIONS RESEARCH/MANAGEMENT SCIENCE (OR/MS) PRACTICE

The Institute for Operations Research and Management Science (INFORMS) presents the INFORMS Prize for Teaching of OR/MS Practice annually to a university or college teacher who excels in teaching the practice of OR/MS. This purpose of this award is to recognize a teacher who has succeeded in helping his/her students to acquire the knowledge and skills necessary to be effective practitioners of operations research, or the management sciences.

Professor Richard Rosenthal is the 2000 recipient of this prestigious award. Dr. Rosenthal has taught hundreds of students at NPS and the University of Tennessee. He is a dynamic, effective and inspiring teacher and mentor, and many of his former students find their lives and careers transformed by the lessons he taught them.

Currently Chair of the Operations Research Department, Dr. Rosenthal leads a department that emphasizes the practical aspects of operations research. As a new faculty member at NPS several years ago, he introduced algebraic modeling languages into the teaching of optimization and developed teaching materials transforming optimization-based decision support systems into a popular topic for students. His teaching has always emphasized the practical aspects of OR/MS and he has supervised many applied thesis projects.

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solving problems with thousands of links and nodes in a few minutes on a personal computer.

Optimally Scheduling EA-6B Depot Maintenance

A current research project of Associate Professor **Robert F. Dell** is to equip the EA-6B Program Office with a desktop, optimization-based decision-support tool to schedule all depot maintenance (standard depot level maintenance, wing center section replacements, and major aircraft modifications) for the EA-6B Prowler fleet. This effort grew from the thesis of **LCDR Bradley Meeks, USN** (September 1999) advised by Professor Dell. **MAJ Ross Baker, USMC** (September 2000) is aiding Professor Dell with final development.

Ranging from Operation Desert Storm to combat actions in the Balkans, EA-6B Prowler aircraft lie at the heart of nearly all tactical aircraft strikes. Providing a fleet capable of such combat actions in the next decade challenges the Prowler community to efficiently schedule EA-6B depot maintenance services. By 2009, EA-6B depots must conduct 80 wing center section replacements, 144 major aircraft modifications and 154 instances of standard depot-level maintenance. There are several complex rules governing when each Prowler is eligible for each service; these rules are also flexible enough to allow more induction schedules than can be evaluated manually in a reasonable amount of time. Because each service removes aircraft from mission inventory for six to 12 months, and performing multiple services together requires less time than performing services independently, services should be combined whenever possible.

LCDR Meek's thesis develops a mixed-integer linear program prototype, EA-6B Depot Maintenance Optimization Model (EDMOM), to help schedule EA-6B aircraft for depot maintenance services. EDMOM minimizes total time aircraft are removed from mission inventory; it produces an induction schedule for the

EA-6B fleet through 2009 that adheres to all appropriate rules and conducts 378 services in only 216 inductions, requiring 2,446 total months. Without combining services, it would require 3,630 months, nearly 50 percent longer.

Visual Perception Issues Pertaining to Military Systems

The Office of Naval Research, Naval Research Laboratory, TENCAP, and Lockheed Martin Corporation currently fund Assistant Professor **William Kreb's** Perception Laboratory to investigate visual perception issues pertaining to military systems. Student and faculty research projects are ongoing in the lab.

LCDR Tom Evanoff, USN (December 1999) was bestowed the Military Operations Research Society Award for his thesis, "Design and Analysis of a Shipboard Visual Navigation Aid

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Figure 1. The Tactical Vectoring Equipment (TVE) shipboard navigation display resulted from the thesis work of LCDR Evanoff to design and analyze a shipboard visual navigation aid for vessels in formation. The TVE display contains a horizontal line of its bicolor (red and white) lights spaced approximately six feet apart on the stern of the carrier.

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for Vessels in a Formation: Tactical Vectoring Equipment.” LCDR Evanoff exploited inexpensive commercial off-the-shelf technology to reduce surface vessel collisions at sea. His visual navigation aid, a TVE display, will enhance shipboard conning officers situational awareness while maneuvering under low-illumination in battle group formation. The TVE will consist of six bi-color red and white lights spaced several feet apart mounted on the stern of an aircraft carrier, similar to the aviation runway displays used to assist pilots on final approach (Figure 1). LCDR Evanoff immersed subjects in a virtual environment to simulate a plane-guard operation. He found that surface warfare officers using the TVE display had fewer bearing and range errors than the normal carrier navigation light configuration while maintaining station 1750 astern of the carrier (Figure 2). The significant results gained

support from VADM Giffin (COMNAVSURFLANT), RADM Gemmill (CNO-N885), RADM Mullen (CNO-N86), and Office of Naval Research (Code 34) to fund a prototype. The land prototype should be ready for testing by June 2000. The FRS Helicopter Squadron HS-10 located at NAS North Island will assist with the land prototype testing to ensure that the display will be invisible to pilots while approaching the carrier. Once the land test is completed, the TVE display will be mounted on an AIRLANT carrier for sea trials later this summer.

In another project, Dr. Albert Ahumada, vision scientist at NASA Ames and NPS visiting professor, and Professor Krebs have been developing image discrimination models that can predict the detectability of target signals in color images. The results of the psychophysical studies may enable engineers to quantify an operators image-sensor-fusion detection performance, provide Operations Research analysts more accurate human detection thresholds for combat models, and gain better insight to the basic understanding of color perception.

Combat Models: The Value of Information in Conflict

The information age, like the industrial revolution before it, has the potential to transform the nature of military operations. The transformation may require dramatic changes in force structure, force organization, and tactics and doctrine. The challenge for defense analysts is to assist senior leadership in making the appropriate decisions. This task is complicated by a dearth of relevant real-world data and by difficulties in applying what we have learned from the past to the increasingly uncertain future. Consequently, combat simulation is an increasingly valuable tool for analysts, and hence decision-makers. Unfortunately, there is a lack of real combat data with which combat models can be validated, and furthermore, most combat models are very large and nonlinear. Therefore, it is difficult to fully explore them. To address these issues, Associate Professor **Tom Lucas’** research has explored: (1) using simple combat models and human experiments to assess the value of information in conflict; (2) using advanced statistical design of experiments to more efficiently search high-dimensional models; and (3) comparing and validating combat models and theory to historical combat data.

Simple combat models and controlled human experiments are used to assess the value of information in conflict and how that information is perceived by military decision-makers. In

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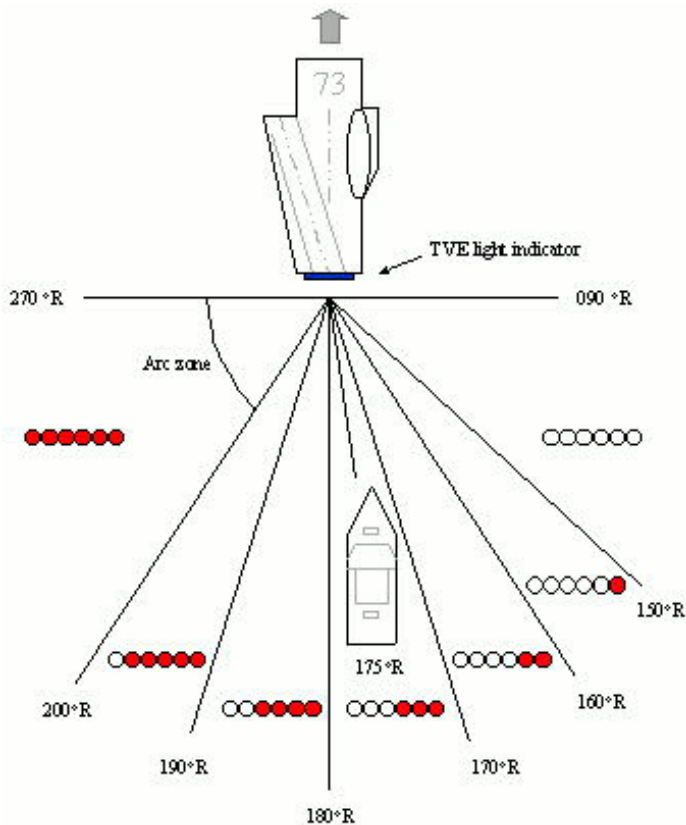


Figure 2. The red and white color system indicates the escort ship's relative position astern of the carrier. The desired station is 175° relative. As the ship's position changes relative to the carrier's stern, the light display changes color indicating approximate degrees off station. The conning officer can also interpret the aircraft carrier's range by the size and spacing of the lights from the combat vessel.

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a series of experiments involving 35 trials on each of 30 military and civilian DoD subjects, **LT John McGunnigle, USN** (September 1999) demonstrated that military decision-makers often do not use information optimally even in a simple stress-free situation. Equally insightful, the military decision-makers significantly overestimated the value of information compared to force advantage, suggesting that they too readily embrace the current enthusiasm for information technologies. Additional computational experiments on modern naval surface combat indicate that (1) increasing information advantage can enhance but occasionally may degrade a force's effectiveness, and (2) increasing force advantage in the same conflict always enhances the combat effectiveness of the forces investigated.

Statistical approaches that efficiently explore high-dimensional combat models with a variety of search strategies, such as full factorial, fractional factorial, Latin-hypercube, group screening searches, and combinations of these designs, are being examined. **Capt Lloyd Brown, USMC** (March 2000), also working with Professor Lucas, studied CNA's agent-based combat simulation Irreducible Semi-Autonomous Adaptive Combat (ISAAC) and found that fractional factorial designs provide almost as much information from ISAAC as full factorial designs with only a fraction of the simulation runs.

There is a dearth of detailed two-sided time-phased (daily) combat data that can be used to validate combat models and theories. Recently, the Dupuy Institute compiled detailed databases of the Battle of Kursk (the largest tank battle in history) and the Battle of the Bulge. **1st LT Turker Turkes, Turkish Army** (March 2000) examined how Lanchester equations and other forms fit the data. It turns out that a wide variety of models fit the data about as well—explaining conflicting findings in the literature. Unfortunately, none of the basic Lanchester models fit the data well, bringing into question their use in combat modeling.

The Battlespace/Information War (BAT/IW) Model and Analysis Tool

Modern military operations depend increasingly on the acquisition and usage of information concerning own, joint, and enemy force identities, locations, and apparent courses of action. The raw information (data) comes from a variety of sensors, and from other sources (SIGINT, ELINT); the products are digested, and that fused product informs decision-makers, who may choose to maneuver, dispatch appropriate weapons, or to seek further information. Weapon

dispatch is followed by effect appraisal; or battle damage assessment (BDA); this effort guides further action. A basic realism is that the data and subsequent actions are subject to errors that tend to degrade seriously system performance; the effects tend to be literally highly nonlinear. Thus the quality of information acquired and utilized can be of paramount importance to system operational success.

Distinguished Professor **Donald Gaver** and Professor **Patricia Jacobs** have constructed a dynamic aggregated model type for quickly analyzing military C4ISR systems that acquire information, process it with realistic time delays (latency), use it to direct actions (e.g. select and apply weapons to targets but the same issues arise in hazard relief and disaster control circumstances), infer the consequences of action (BDA), and repeat the process. The model is called Battlespace/Information War (BAT/IW). It realistically accounts for delays and uncertainties in enemy (and own) asset detection, classification, and weapon-target pairing effectiveness: the latencies and error rates characteristic of given system elements of systems-of-systems. It incorporates these system limitations into a high-level overall end-to-end scoping model that facilitates analysis of specific system sensitivities and opportunities for tradeoffs, where payoff is measured in terms of opponent kills (by type), exchange rates, campaign duration, the effects of platform sustainability, and weapons costs. The model emphasizes such issues as the degrading effects of either opponents incapability to identify false targets and decoys.

Development of BAT/IW has been sponsored by the Navy (N6C) and the model is currently being applied to better understand the effect of various system architectures and operational concepts in strike warfare, airborne electronic attack and suppression of enemy air defenses, and to analyze Network-Centric operational concepts.

OR Models and Algorithms Convert Real-Time Information into Decisions

Current military leaders are predicting a future battlefield that is much different than that of today. *Joint Vision 2010* and *Army Vision 2010* create a framework for planning a future force to succeed on that battlefield. Information superiority is the critical enabling technology that will allow U.S. forces to gain dominant battlefield awareness that will yield a much more accurate assessment of friendly and enemy operations. Current Army experiments include a computer in every

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vehicle and even on every individual soldier. Operations research models and algorithms will be critically important in converting the glut of data into useful information for decision-makers. The thesis of **CPT Robert Bradford, USA** (June 2000), has designed an Architecture for Dynamic, Distributed Military OR (ADDMOR) to solve battlespace decision problems involving dynamic road networks using algorithms and data that are distributed over a dynamic, distributed computing network. This work is part of the Loosely Coupled Components faculty/student research group lead by Professor **Gordon Bradley** and Assistant Professor **Arnold Buss**.

The ADDMOR assumes that forces on the battlespace will be connected through a network of heterogeneous computing devices (for example, cell phones, personal digital assistants, personal computers, and super computers). This network will be changing as the forces move in the battlespace. The constantly changing data will be distributed across the network. The design is based on free, currently available technology including HTML servers to support Java servlets that will allow access to data, models and algorithms by any computer on the network that has an Internet browser. CPT Bradford demonstrated the architecture by constructing and testing a system to optimize the movement of personnel and materials on the battlespace road networks. The units in the battlespace are moving and the road network is changing as the battle unfolds. He demonstrated the capabilities of the system by constructing an application that would allow a medic to request directions to the nearest aid station. The request is submitted via a web page to an HTML server running a Java servlet that coordinates the construction of a solution. The servlet marshals the most current data on unit locations and road conditions (distributed across the computing network) and locates on the network an appropriate network optimization algorithm that is then used to construct a solution. The answer is returned to the medic in a web page that is appropriate for his computer (cell phone, personal digital assistant, computer, etc.). The ADDMOR is applicable to a wide range of other problems in warfare and operations other than war where the use of OR models and algorithms to convert real-time data into useful information for military decision-makers will contribute to better decisions.

Ranger Air Load Planner

The United States Army 75th Ranger Regiment conducts combat parachute operations as part of United States Special

Operations Command (USSOCOM). Currently the largest deployable asset of USSOCOM, the Rangers are required to plan and execute large-scale parachute assaults into hostile theaters with little or no notice. The thesis of **CPT Maximo A. Moore, USA** (June 2000), provides Ranger air load planners a tool to rapidly plan feasible equipment loads. The system is called the Java Ranger Air Load Planning Heuristic (JRALPH). JRALPH is simple to learn and operate, provides load solutions based on existing, United States Air Force approved load plans, and supports dynamic decision support with rapid solution return. The thesis, which was advised by Professor **Gordon Bradley**, also contains a mixed-integer programming optimization model used to validate JRALPH.

The success of any military tactical operation depends on preparation before attempted execution. The Rangers cannot rehearse movement from the landing site to the assembly area until the air load planner tells them in which aircraft they will be arriving at the objective area. Failure to generate a timely, robust load plan will result in wasted mission preparation time and possible mission failure. In September 1999, NPS faculty member **LTC Joel Parker, USA** and CPT Moore attended a Ranger training exercise where they observed a Ranger Battalion staff conduct air load planning. For the observed mission, the manual air load planning took one man 6-8 hours using a procedure that has not changed in 15 years. They met with various members of both the Regimental and Battalion staffs. These Rangers agreed that a planning assistance tool for air load planning would be welcome.

JRALPH presents the planner with an air load plan in a graphical user interface (GUI) that helps the planner visualize changes. JRALPH relieves the planner from tedious manual load planning and re-planning sessions required for final load plan approval by the Regimental Commander. During negotiations with subordinate unit commanders for load plan changes, the planner will be able to quickly assess the quality of their proposals; this is an automated capability that does not currently exist. JRALPH is written in the Java programming language. For a sample problem of a battalion-size operation with 11 different types of items and 11 aircraft, JRALPH explicitly evaluates over 16,000 individual load templates. JRALPH accomplishes this in less than one second on a contemporary personal computer. This thesis provides not only a demonstration of JRALPH's capabilities through a sample mission load plan, but also provides a

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working product that can be adapted for use in air load mission planning by all units under USSOCOM.

Agent-Based Simulation Modeling

Urban warfare, information warfare, and operations other than war are a few of the important new concepts that concern military thinking. These new ideas require approaches to analysis that are different than those that have been traditionally conducted. DoD has relied on large simulation models to perform analysis on issues such as force structure, tactics, and doctrine. A new model that has emerged in recent years is based on autonomous, adaptive agents. Maj Ronald Woodaman, USMC (June 2000), working with Professor Gordon Bradley and Assistant Professor Arnold Buss, has developed a component framework for combining an agent-based approach with simulation modeling, building on the Simkit simulation package. Maj Woodaman is applying his framework to urban warfare scenarios that are of great interest to the Marine Corps. Combining simulation modeling with an agent-based approach stands to offer benefits available in both types of modeling.

The simulation models are based on a discrete-event

paradigm, in which events occur as particular epochs of simulated time. These events trigger a change of the systems state followed by further events being scheduled to take place in the future. The agent components consist of rules and meta-rules that describe how entities react to the state of the environment and of other agents. Each rule is relatively simple. The meta-rules are rules for how agents decide which rules are to be used in various situations. Adaptation is modeled by parameterizing the rules and the meta-rules. Together, the simple rules combine to produce complex behaviors from the simulation entities.

The agent-based approach is particularly useful for the urban scenarios studied in Maj Woodaman's thesis since they involve much smaller numbers of entities than traditional theater-level simulation models. Each unit's impact on the outcome is much greater. Information plays a much bigger role as well. Here, asymmetric information is modeled by each agent having its own perception of the state of the system (environment and other entities). Since each agent not only can have different sets of rules, but could have them respond differently due to adaptation, complexities can be captured in the model that would be difficult by any other means.

Senior Lecturer (emeritus) Wayne P. Hughes, Jr., (standing) formerly of the Department of Operations Research, was presented with the Department of the Navy Distinguished Civilian Service Award at his 70th Birthday Bash. The award is the highest honor bestowed upon a civilian by the United States Navy. "Professor Hughes has made significant and lasting contributions to education, analysis and innovation within the Navy during his tenure at NPS," the award reads in part. "He is widely recognized as one of the giants of Naval Operations Analysis, and has contributed extensively to its development. His critically acclaimed book, *Fleet Tactics: Theory and Practice*, now in its second edition, is the definitive work in analytical modeling of how naval units engage in combat." Professor Hughes has also served as NPS' first Chair of Tactical Analysis and as the Chair of Applied Systems Analysis.

